Art. XXVII.—*Some Quantitative Laws of Incubation and Gestation.*

By Alexander Sutherland, M.A.

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It is known in a general way that the time required for hatching out the eggs of cold-blooded animals is dependent on the temperature at which they are kept. Professor McIntosh ("Nature" xxxi., p. 555) says that salmon eggs left in the sea, take from 95 to 120 days to hatch, but that when transferred to a warm room they hatch in 60 days. Bertram, in his "Harvest of the Sea," says that herring eggs will hatch slowly or quickly according to the temperature, a difference of 50 days being possible. As a rule herring eggs take from 11 to 40 days, graylings from 14 to 40, codfish 5 to 42, tench 6 to 14, gurnards 7 to 35, stickleback 10 to 30, and so on, the higher the temperature the less the time. But in connection with a book on which I have long been busy, I required more definite information as to the relation of hatching-time to temperature, and therefore I instituted a long series of hatchings of frogs' eggs. During two winters I took the eggs of a species which Professor Spencer identified for me as *Hyla aurea*, and hatched its eggs in sets at graduated temperatures. This species extrudes an unusual number of eggs, the average of 14 sets that I counted being over 3000 to each. It was easy therefore to get ten sets of 100 each, which could with certainty be regarded as of similar condition. I put them over lamps and kept them at temperatures, as nearly uniform as I could, ranging from 10° C. to 33° C.

Six series of experiments thus conducted satisfied me that the time required for hatching was inversely proportional to the square of the excess of the temperature above a certain fixed temperature. But in every series there occurred one or more failures through accidental variations in temperature. I, therefore, in September last, carried out a new series of experiments, floating each set of eggs in a large body of water which could not easily vary during intervals between observation. Even here one set was somewhat affected by a rise of 3° C. lasting for 4 hours, during an unavoidable absence. I give the table herewith, without any attempt at compensating for errors. The law which they clearly indicate is that

$$t = \frac{m}{(T+a)^2}$$

where t is the time of hatching, T is the temperature at which the eggs are kept; m and a are constants, the latter being of course the fixed temperature referred to. The last column gives the time (in hours) which the eggs would have taken to hatch according to this law, assuming $m = 40,200$; and $a = 1{\cdot}3°$ C. for this species.

Table I.

No.	Average Temperature.	Time Observed.	Time Calculated.
1	31·6° C	Killed by heat.	
2	29·3° C	43 hours	42·9 hours
3	28° C	45 ,,	46·8 ,,
4	24·1° C	62 ,,	62·2 ,,
5	22·8° C	68 ,,	69·3 ,,
6	21·7° C	71 ,,	76 ,,
7	17·6° C	114 ,,	113·5 ,,
8	17·5° C	114 ,,	114 ,,
9	15·8° C	138 ,,	137·5 ,,

No. 6 is the set already referred to as having been marred by an accident; but the general agreement of the figures can leave no doubt as to the accuracy of the law.

In the formula given it is plain that a temperature of $-1{\cdot}3°$ C. would be that at which the eggs would take an infinite time to hatch, or, in other words, would never hatch at all; but at temperatures somewhat above this we may be sure that other circumstances would interfere to prevent the development of the tadpole.

The quantity m is constant only for a given species; but in what follows of this paper, enough will be seen to make it probable that in comparing species with species, it is a quantity varying directly as the sixth root of the weight of the fully matured animal. So far as I can depend on the very few and very rough observations made as to the hatching time of lizards, snakes, turtles and alligators, this belief is fairly well borne out. But, as the unreliable nature of these figures prevents more than a sort of *prima facie* evidence, let me pass by preference to others in which there is more accuracy, though still the observations are often merely approximate.

All birds and mammals, except the monotremata, and, as I shall show in a future paper, the marsupiata, keep at a temperature which may, for the purposes of this enquiry, be considered constant, so that in the following investigation we may neglect temperature variations, as the figures to be dealt with are not accurate enough to allow of refined adjustments. Excluding the monotremata and marsupiata, the extremes of health temperature for birds and mammals would be 37° C. and 43° C., or a range of only 6° C. We may therefore assume that all birds sitting on their eggs keep them at a tolerably definite temperature. Any given species, therefore, will take a certain fairly definite time to hatch out its eggs. Temperature, we know, counts for something; a set of hen, duck or turkey eggs placed in a warm dry situation will hatch out two or three days before another set in a damp cold place. But, in view of the roughness of the observations of naturalists, we shall assume that each species takes a tolerably definite time in hatching, the hen for instance, 21 days, and the turkey, 28.

What, then, is the reason for the difference in time, seeing that in all cases the temperatures are much the same? Why does a humming-bird take 10 days, or a wren 10, while a dove takes 18, a fowl 21, a turkey, 28, an ostrich about 50? St. George Mivart says: "The period of incubation is much related to the size of the bird." I propose in this paper to determine the nature of that relation, and to show that the time of incubation is directly proportional to the sixth root of the weight of the bird when mature.

The following preliminary table will serve to illustrate this relation and show that $t = n\sqrt[6]{w}$, where t = time in days.

w = weight in lbs.

$n = 20$.

TABLE II.

Name.	Weight.	Time Observed.	Time Calculated.
Humming Bird	150 grains	10 days	10·5 days
Wren	135 ,,	10 ,,	10·3 ,,
Goatsucker	2½ oz.	14 ,,	14·6 ,,
Lark	4 ,,	15 ,,	15·8 ,,
Kingfisher	7½ ,,	17 ,,	17·6 ,,
Pigeon	12¼ ,,	18 ,,	19 1 ,,
Pheasant	2½ lbs.	24 ,,	23·3 ,,
Common Fowl	3 ,,	21 ,,	24 ,,
Guinea Hen	9 ,,	28 ,,	28·9 ,,
Duck	6 ,,	28 ,,	27 ,,
Turkey	12 ,,	29 ,,	30·2 ,,
Goose	12 ,,	32 ,,	30·2 ,,
Eagle	12 ,,	30 ,,	30·2 ,,
Ostrich	250 ,,	38 to 60 days	50·1 ,,

In an appendix to this paper I shall give a list of 105 birds, for which I have been able to obtain records of the weight and of the incubation period of each. I have, indeed, found records of the weights of over 500 species and incubation periods of an almost equal number; but in only these 105 cases can both items of information be had for the same bird. They are sufficient, however, to show that the law enunciated holds good with only one notable exception, the Apteryx, which is wholly isolated if the figures given by Buller are to be accepted. There is one dubious case—the Emu. But in such an enquiry allowance must be made for the want of definiteness in the figures. Many observers are content to say that a bird broods for 3 or 4 weeks. Even so careful a writer as Brehm, gives very many of his incubation periods in the same inaccurate fashion. Nor do the authorities agree well together. For a bird so well-known as the Swan, Brehm gives 48 days as the period; poultry books say 6 weeks, while Bechstein, a very competent authority, gives 5 weeks. In regard to the ostrich, Anderson gives 38 days, Brehm gives 45 to 52, while St. George Mivart says 50 to 60, and half-a-dozen other authorities give various intermediate periods. In all such cases I have taken the mean. But there are many, no doubt, not to be accepted as more than very rough approximations.

In a few cases where, instead of the name of the authority for the weight, the word "calculated" occurs, it means that, being unable to find the weight of a species, but having discovered that of a closely allied species, presumably of the same shape, I have calculated the weight of the one from that of the other on the assumption that they are proportional to the cubes of the lengths.

If we apply the same sort of investigation to the Mammalia as a whole, we find that for the period of gestation the law

$$t = n \sqrt[6]{w}$$

holds with only moderate accuracy. But if we consider any one order at a time, the coincidence of observed and calculated times is sufficient to establish the law conclusively. For instance, the following is a list of all the carnivora for which I can obtain information. For this order the constant n is equal to 41.

TABLE III.

Popular Name.	Specific Name.	Weight, in lbs.	Authority.	Time Calculated.	Time Observed.	Authority.
				Days.	Days.	
Cat	Felis maniculata	6	Experiment	55	55 to 56	Mivart, Brehm, &c.
Wild Cat	Felis catus	16	Brehm	65	63	Brehm
Lynx	Lynx vulgaris	18	Brehm	66·5	70	Brehm
Chaus	Lynx chaus	15	Brehm	64·4	70	Brehm
Lion	Felis leo	490	Jerdon	113	110	Average of seven
Puma	Felis concolor	160	Calculated	95·5	96	Brehm
Tiger	Felis tigris	332	Brehm	108	100 to 105	Brehm
Leopard	Felis panthera	150	Calculated	94·7	90	Brehm
Ferret	Putorius furo	1	Cyclopædia	41	{ 35 { 42	Brehm Vogt.
Weasel	Putorius vulgaris	½	Cyclopædia	36·5	35	Brehm
Otter	Lutra vulgaris	19	Flower & Lydekker	67	63	Brehm
Polecat	Putorius fœtidus	6		55	55 to 60	Brehm
Wolverine	Gulo borealis	96	Brehm	87·7	90	Vogt.
Marten	Mustela martes	8		57	63	Brehm
Badger	Meles taxus	44	Brehm	77·1	84 to 105	Brehm
Racoon	Procyon lotor	15	Cyclopædia	64·4	63 to 70	Brehm
Brown Bear	Ursus formicarius	550	Brehm	187	180	Vogt
Polar Bear	Ursus maritimus	800	Vogt.	199	210	Brehm
Land Bear	Ursus arctos	440	Brehm	180	180	Brehm
Jackal	Canis aureus	22	Brehm	74·7	63	Brehm
Wolf	Canis lupus	90	Brehm	86·9	70	Landois
Fox	Canis vulpes	{ 6 { 16	Jerdon Brehm	55 65	62 63	Brehm Landois

The dog family are here the most abnormal, and, among domesticated dogs, although the larger varieties have a longer gestation period than the smaller, the difference is not sufficient to make the times accord with the law given.

The ruminants form another group fairly consistent within itself; but for them the constant n must be made equal to 80.

The camel and giraffe families are left out of the following list, the former for want of weights of individuals, the latter because the gestation period is abnormally long. But of the Cervidæ, Capridæ, and Bovidæ, the following are all the species for which I can find both weights and gestation periods recorded.

TABLE IV.

Popular Name.	Specific Name.	Weight, in lbs.	Authority.	Time Calculated.	Time Observed.	Authority.
				Days.	Days.	
Roebuck	Capreolus capræa	50	Brehm	153	160	Brehm
Stag	Cervus elaphus	450	Brehm	221	280	Brehm
Fallow Deer	Dama vulgaris	220	Brehm	196	240	Brehm
Elk	Alces palmatus	750	Brehm	242	259	Brehm
Saiga	Colus tartaricus	120	Brehm	178	165	Brehm
Gemsbok	Capella rupicapra	90	Brehm	169	150	Brehm
Goral	Nemorhœdus goral	200	Jerdon	193	180	Brehm
Nilgau	Portax pictus	800	Brehm	244	240	Brehm
Elend	Busephalus oreas	1000	Brehm	253	282	Brehm
Koodoo	Strepsicorus kudu	400	Brehm	217	210 to 240	Brehm
Wild Cattle	Bos taurus	800	Brehm	244	280	Brehm
Bison	Bison europæus	1320	Brehm	265	280	Brehm
Yak	Bos grunniens	1100	Brehm	257	270	Brehm
Musk Ox	Ovibos moschatus	800	Brehm	244	270	Brehm
Mufflon	Ovis musimon	100	Brehm	172	147	Brehm
Argali	Ovis argali	400	Brehm	217	210	Brehm
Ibex	Capra ibex	170	Brehm	188	150	Brehm
Reindeer	Rangifer tarangus	400	Cyclopædia	217	210	Brehm
Musk Deer	Moschus moschiferus	50	Cyclopædia	153	180	Brehm
Sheep	Ovis aries	100	Av. of 7 weighed	172	150	Av. of 5 observers
Goat	Capra hircus	100	Calculated	172	154	Av. of 4 observers

More accurate results may be had by taking the families separately and adopting for each its own value of n, these values being nearly, but not quite, equal. In the same way by putting $n = 55$ we find that the *Suidæ* and *Hippopotamidæ* make a consistent group, though not running uniformly with the rest of the *Artiodactyls.*

The period of gestation among these animals is generally only roughly determined by observing in what months the sexes come together, and then observing in what month the young are born. How fallacious this may be has been shown by Bischoff in the case of the Roebuck, the female of which does not produce her young until more than nine months after the rutting season. But it is now known that this is not the period of gestation, for the spermatozoa lie for four months in the uterus without fertilising the ovum, so that the real period is only some five months. The same phenomenon is observed with bats and other mammals. Selenka has shown that with the Virginian Opossum the time from copulation to birth is 13 days while the actual time of gestation is only $7\frac{5}{6}$ days. So in the U.S. Fisheries' Report of 1884, the statement is made that while the males of *Embiotocidæ* impregnate the females in autumn the young are born alive in the following summer. Hence the spermatozoa must lie inactive for many months.

It is quite probable, as the foregoing list suggests, that beside the Roebuck, there are other species of deer in which the same peculiarity occurs to a less extent. Perhaps the same thing occurs in the case of the Beaver which is a very aberrant species, as will be seen from the list given in the appendix of all the Rodentia for which information is available. The *Perissodactyla* make another consistent group. All the species for which information is available are given in the appendix.

In dealing with the mammals we have found it necessary to give different values to the constant. There are two biological reasons for this. The first is that some animals are carried by their mothers till fairly well able to take care of themselves. A calf, or a foal, or a young deer is sufficiently matured to trot after its mother in a few hours after birth; while a kitten, or a puppy, or a tiger cub is for a long time helpless. One animal therefore remains in its mother's womb until tolerably complete as compared with another. This causes the value of n to be high in ruminants, and higher still in Proboscidea; while in Carnivora and Rodentia it is low, but of approximately equal value, 41 for the first; 35 for the second.

The first law, stated in its most general form, is this:—"For animals of the same size the time of embryo development is inversely proportional to the square of the temperature, that temperature being reckoned from a definite point."

The second law, similarly stated, is that:—"At the same temperature, the period of development is directly proportional to the sixth root of the weight of the mature animal."

This latter law is capable of a certain simplification. If two animals are of different sizes, but of the same shape, the weights of their bodies are proportional to the cubes of their lengths. The law in that case would be:—At the same temperature, among animals of the same shape, the period of development is directly proportional to the square root of the length.

Thus we have

$$t = n\sqrt{l}$$

but this is the same as

$$l = ft^2$$

where $f = \frac{1}{n^2}$.

Now this is the well-known equation for the space traversed by a body moving under the influence of a constantly accelerating force, and the significance of the law therefore is that if we consider the germinal point as the starting place, and imagine the embryo to travel outwards from it to the periphery, the velocity of the motion will be such as would result from a constantly accelerating force propelling it from the germinal spot outwards.

In the appendix a list is given of the gestation periods of the rodents, the family Leporidæ being set down apart from the others as requiring a lower value of the constant. The Beaver is a very aberrant case. The only four species of Perissodactyls for which I can get information form a fairly consistent group. For them the value of the constant is very high, but in the Proboscidea it rises higher than in any other of the lower families, reaching a value of 120. In the Prosimia it appears to be only equal to the value of n in the ruminants; but in the Quadrumana it rises to 160, and in mankind remains at about the same value.

This increase in the value of n as nerve development progresses, is a ready corollary from Von Baer's law, but many difficulties arise in the attempt to work out the relation in a general way.

One may almost risk the prediction that the laws above stated will be found to combine in this fashion:—

I.—Reckoning t to be the time from the fusion of the nuclei to some definite point in development, say, the capacity of the young animal to stand, walk or swim; T to be the temperature at which development takes place, and w to be the weight of the mature animal. Then as a first approximation

$$t = \frac{k\sqrt[6]{w}}{T^2}$$

T being reckoned from a definite point; not necessarily any of the recognised zeros.

II.—But the quantity t tends decidely to increase with increase of nerve complexity, as gauged by size and efficiency of brain.

Appendix I.

INCUBATION PERIODS OF BIRDS.

$t = n\sqrt[6]{w}$ where $n = 20$.

Popular Name.	Specific Name.	Weight.	Authority.	Time Calculated.	Time Observed.	Authority.
				Days.	Days.	
Swallow	Hirundo rustica	1 oz.	Experiment	12·5	12	Brehm
Canary	Dryospiza canaria	600 grs.	Bp. Stanley	13·2	14	Jones
Greenfinch	Chloris hortensis	480 grs.	Bp. Stanley	12·9	13	Jones
Goldfinch	Carduelis elegans	540 grs.	Bp. Stanely	13·1	13	Jones
Goatsucker	Caprimulgus kelaartii	$2\frac{1}{2}$ oz.	Jerdon	14·6	14	Jerdon
Trogon	Harpactes fasciatus	$2\frac{1}{2}$ oz.	Audubon	14·6	20 (?)	Brehm
Halcyon	Halcyon leucocephalus	$7\frac{1}{2}$ oz.	Audubon	17·6	17	Brehm
Woodpecker	Chrysocolaptes sultaneus	6 oz.	Jerdon	17	14	Jerdon
Hedge Sparrow	Tharraleus modularis	1 oz.		12·5	14	Jones
Wryneck	Yunx torquilla	$1\frac{1}{2}$ oz.	Jerdon	13·4	14	Brehm
Nuthatch	Sitta cæsia	$\frac{1}{2}$ oz.	Jerdon	11·2	13	Brehm
Shrike	Lanius lahtora	2 oz.	Jerdon	14·1	15	Brehm
Woodshrike	Tephrodornis silvicola	$1\frac{1}{2}$ oz.	Jerdon	13·4	13	Brehm
Wren (Common)	Troglodytes ædon	135 grs.	White's Selbome	10·3	10	Mivart
Wren (Winter)	Troglodytes hiemalis	300 grs.	Audubon	11·9	13	Brehm
Girlitz	Serinus hortulans	320 grs.	Audubon	12	10	Newton
Chaffinch	Tringilla cœlebs	1000 grs.	Audubon	14·4	14	Newton
Lark	Alauda arvestris	1700 grs.	Audubon	15·8	15	Newton
House-Sparrow	Passer domesticus	1000 grs.	Audubon	14·4	14	Newton
Piping Crow	Gymnorhina tibicen	5700 grs.	Experiment	19·3	21	Brehm
Martin	Chelidon urbica	500 grs.	Calculated	12·9	12	Brehm

INCUBATION PERIODS OF BIRDS.—*(Continued).*

Popular Name.	Specific Name.	Weight.	Authority.	Time Calculated.	Time Observed.		Authority.
				Days.	Days.		
Sand Martin	Cotyle riparia	400 grs.	Calculated	12·4	14		Brehm
Flycatcher	Muscicapa albicollis	600 grs.	Calculated	13·2	14		Brehm
Robin Red-breast	Erithacus rubeolus	700 grs.	Calculated	13·7	14		Brehm
Sedge Warbler	Calamodus phragmitis	500 grs.	Calculated	12·9	14		Brehm
Pendulous Titmouse	Ægithalus pendulinus	400 grs.	Calculated	12·4	14		Brehm
Long-tailed Tit	Orites caudatus	500 grs.	Calculated	12·9	13		Brehm
Honeysucker	Nectarinia metallica	600 grs.	Calculated	13·2	14		Brehm
Humming Bird	Trochilus colubris	150 grs.	Calculated	10·5	10		Brehm
		12 lbs.	Jerdon	30·2		35	Brehm
Eagle (Golden)	Falco chrysaëtos	15 lbs.	Jerdon	31·4	21 to 35		
		11 lbs.	Audubon	29·8		21	Gray
Snake Buzzard	Circaëtus brachydactylus	$4\frac{1}{4}$ lbs.	Jerdon	25·4	28		Jerdon
Osprey	Pandion haliætus	$3\frac{1}{2}$ lbs.	Jerdon	24·7	24		Brehm
Vulture	Vultur cinereus	19 lbs.	Jerdon	32·6	32		Brehm
Kite	Hydroictinia govinda	$7\frac{1}{2}$ oz.	Jerdon	17·7	21		Brehm
Goshawk	Astur palumbarius	46 oz.	Jerdon	17·6	18 to 20		Brehm
Wood Owl	Syrnium newarnese	$2\frac{1}{3}$ lbs.	Jerdon	23	21		Brehm
Eared Owl	Strix otus	8 oz.	Jerdon	17·8	21		Brehm
Scops Owl	Ephialtes pennatus	$2\frac{3}{4}$ oz.	Jerdon	16·7	21		Brehm
Owlet	Athene brama	4 oz.	Jerdon	15·9	15		Brehm
Stock Dove	Palumbœna eversmanii	$7\frac{1}{2}$ oz.	Jerdon	17·6	17		Brehm
Ring Dove	Columba palumbus	$6\frac{1}{2}$ oz.	Jerdon	17·2	17		Darwin
Pigeon	Columba livia	$12\frac{1}{4}$ oz.	Darwin	19·1	18		Brehm
Common Fowl	Gallus	4 lbs.	Experiment	25·1	21		Brehm

INCUBATION PERIODS OF BIRDS.—*(Continued).*

Popular Name.	Specific Name.	Weight.	Authority.	Time Calculated.	Time Observed.	Authority.
				Days.	Days.	
Jungle Fowl	Gallus ferrugineus	2 lbs.	Le Messurier	22·5	21	Brehm
Pheasant	Phasianus colchicus	$2\frac{1}{2}$ lbs.	Brehm	23·3	24	Brehm
Guinea Hen	Numida meleagris	9 lbs.	Poultry Books	28·9	28	Poultry Books
Peahen	Pavo cristatus	$8\frac{1}{4}$ lbs.	Le Messurier	28·6	{ 28 30	Poultry Books Brehm
Turkey	Meleagris gallopavo	10 lbs.	Exp. average of 7	29·3	27 to 30	Brehm
Horned Pheasant	Ceriornis satyra	$4\frac{1}{2}$ lbs.	Jerdon	25·6	26	Brehm
Kaly Pheasant	Gallophasis albocristatus	3 lbs.	Jerdon	24	24	Brehm
Himalaya Snowcock	Tetraogallus himalayensis	$6\frac{1}{2}$ lbs.	Jerdon	27·3	28	Brehm
Snow Partridge	Lerwa nivicola	18 oz.	Jerdon	20·7	22	Brehm
Chukkor Partridge	Caccabis chukor	20 oz.	Jerdon	20·8	22	Brehm
Common Quail	Coturnix communis	$3\frac{3}{4}$ oz.	Jerdon	15·7	18	Brehm
Godwit	Scolopax hudsonica	9 oz.	Audubon	18·2	17 to 18	Brehm
Woodcock	Scolopax rusticola	12 oz.	Jerdon	19	18	Brehm
Woodsnipe	Gallinago nemoricola	6 oz.	Jerdon	17	18	Brehm
Common Snipe	Gallinago scolopacinus	$4\frac{1}{2}$ oz.	Jerdon	16·2	15	Brehm
Curlew, Red-billed	Ibidorhynchus struthersii	$9\frac{1}{2}$ oz.	Jerdon	18·3	16	Brehm
Ruff	Philomachus pugnax	6 oz.	Le Messurier	17	19	Brehm
Partridge	Perdix cinerea	1 lb.	Audubon	20	{ 21 22 26	Jones Audubon Brehm
Sandpiper	Tringa subarquata	$2\frac{1}{4}$ oz.	Audubon	13·8	14	Brehm
Sea Sandpiper	Tringa maritima	$3\frac{1}{4}$ oz.	Audubon	14·7	16 to 17	Brehm
Heron	Ardea nobilis	4 lbs.	Le Messurier	25·1	21	Brehm

INCUBATION PERIODS OF BIRDS.—(*Continued*).

Popular Name.	Specific Name.	Weight.	Authority.	Time Calculated.	Time Observed.	Authority.
				Days.	Days.	
Ibis	Geronticus papillosus	3¼ lbs.	Jerdon	24·3	25	Brehm
Stork	Ciconia alba	8 lbs.	Le Messurier	28·3	28 to 31	Brehm
Flamingo	Phœnicopterus roseus	10 lbs.	Jerdon	29·3	32	Brehm
Clattering Rail	Rallus crepitans	11 oz.	Audubon	18·8	21	Brehm
Gallinule	Gallinula chloropus	12 oz.	Audubon	19·1	20	Brehm
Prairie Hen	Tetrao cupido	2 lbs.	Audubon	22·5	18 or 19	Brehm
Knot	Tringa islandica	6 oz.	Audubon	17	16	Brehm
Avocet	Recurvirostrata americana	15 oz.	Audubon	19·8	17 to 18	Brehm
Stilt	Himantopus nigricollis	5¾ oz	Audubon	16·9	16	Brehm
Swiss Plover	Charadrius helveticus	6½ oz.	Audubon	16·5	16	Brehm
Shield Drake	Vulpanser tadorna	3 lbs.	Audubon	24	26	Jones
Domestic Duck	Anas domestica	6 lbs.	Exp. average of 7	27	28	Poultry Books
Mallard	Anas boschus	2¾ lbs.	Audubon	23·6	21	Landois
Teal	Querquedula angustirostris	24 oz.	Le Messurier	21·4	21	Brehm
Wild Goose	Anser cinereus	12 lbs.	Jerdon	30·2	32	Brehm
Cormorant	Phalacrocorax carbo	7½ lbs.	Audubon	28·0	28	Brehm
Crested Grebe	Podiceps cristatus	2½ lbs.	Audubon	23·3	21	Brehm
		2¼ lbs.	Bp. Stanley	23		
Pochard	Clangula glaucion	2 lbs.	Le Messurier	22·5	22	Brehm
Snow Goose	Anser hyperboreus	6¾ lbs.	Audubon	27·5	28	Brehm
Canada Goose	Anser canadiensis	6½ lbs.	Audubon	27·3	28	Brehm
Ruddy Sheldrake	Casarca rutila	4 lbs.	Jerdon	25·1	22 to 23	Naumann
Pelican	Pelecanus onocrotalus	25 lbs.	Jerdon	34·2	38	Brehm
Oyster Catcher	Hæmatopus palliatus	1¼ lbs.	Jerdon	20·8	21	Brehm

INCUBATION PERIODS OF BIRDS.—*(Continued).*

Popular Name.	Specific Name.	Weight.	Authority.	Time Calculated.	Time Observed.	Authority.
				Days.	Days.	
Seagull	Larus argentatus	12 oz.	Average of several	19	18	Brehm
Spotted Redshank	Totanus fuscus	8 oz.	Le Messurier	17·8	15	Brehm
Swan	Cygnus buccinator	$19\frac{1}{2}$ lbs.	Audubon	32·8	35	Bechstein
Skua	Lestris catarractes	3 lbs.	Calculated	24	28	Brehm
Herring Gull	Larus argentatus	22 oz.	Audubon	21·1	18	Brehm
Guillemot	Uria troile	2 lbs	Audubon	22·5	24	Brehm
Large-billed Guillemot	Uria brunnichii	$2\frac{1}{4}$ lbs.	Audubon	23	30	Brehm
Cormorant	Phalocrocorax floridanus	$3\frac{1}{2}$ lbs.	Audubon	24·7	28	Brehm
Pomarine Jager	Lestris pomarinus	$1\frac{1}{2}$ lbs.	Audubon	21·4	28 (?)	Brehm
Red-headed Duck	Ferina anas	2lbs. 7oz.	Audubon	23·2	22	Brehm
Bonaparte's Seagull	Larus bonaparti	10 oz.	Audubon	18·5	18	Brehm
Ostrich	Struthio camelus	250 lbs	Various	50·1	50 to 60	Mivart
		165 lbs.	Brehm	46 7	45 to 52	Brehm
Apteryx	Apteryx oweni	4 lbs.	Buller	23·3	38	Anderson
					42	Buller
Great Bustard	Otis tarda	20 lbs.	Jerdon	33	29	Brehm
Indian Bustard	Eupodotis edwardsii	27 lbs.	Jerdon	34·6	35	Brehm
Rhea	Rhea americana	54 lbs.	Calculated	38 9	39	Brehm
Emu	Dromæus novæ-hollandiæ	100 lbs.	Calculated	43·1	58 (?)	Brehm
					49	Sclater
					30	Wallace
Cassowary	Casuarius galeatus	100 lbs.	Calculated	43·1	58	Brehm
					52	Nicholls
					65	Landois

Appendix II.

RODENTS (excluding Leporidæ). $t = n \sqrt[6]{w}$ where $n = 35$.

Popular Name.	Specific Name.	Weight.	Authority.	Time Calculated.	Time Observed.	Authority.
				Days.	Days.	
Mouse	Mus musculus	1 oz.	Average of 7	22	22 to 24	Weissman
Rat	Mus decumanus	12 oz.	Average of several	33·4	35	Landois
Marmot	Arctomys alpinus	2 lbs.	Calculated	39·3	35	Brehm
Beaver	Castor fiber	35 to 58 lbs.	Morgan	66·4	90 to 120	Morgan
		44 to 66 lbs.	Brehm	68·3		
Dormouse	Myoxus glis	4 oz.	Cyclopædia	27·8	24 to 30	Brehm
Squirrel	Sciurus europæus	8 oz.	Brehm	31·2	28	Brehm
Guinea-Pig	Anæma porcellus	2 lbs.	Experiment	39 3	49	Landois
		1 lb. 3 oz.	Darwin	36·1	28 to 35	Brehm
Zizel	Spermophilus citillus	1 lb.	Brehm	35	25 to 30	Brehm
Porcupine	Histrix cristatus	33 to 44 lbs.	Brehm	64·2	49 to 63	Brehm

LEPORIDÆ. $t = n \sqrt[6]{w}$ where $n = 24$.

Popular Name.	Specific Name.	Weight.	Authority.	Time Calculated.	Time Observed.	Authority.
Rabbit	Lepus cuniculus	$2\frac{3}{4}$ lbs.	Average of 4	30	30 to 32	Various
Hare	Lepus vulgaris	8 lbs.	Average of 3	34	32	Landois

PERISSODACTYLA. $t = n \sqrt[6]{w}$ where $n = 108$.

Popular Name.	Specific Name.	Weight.	Authority.	Time Calculated.	Time Observed.	Authority.
Horse		823 lbs.	Stonehenge	331	330	Brehm; Youatt, &c.
Ass		400 lbs.	Calculated	293	290	Brehm
Tapir		1500 lbs.	Calculated	366	315	Brehm
Rhinoceros		4500 lbs.	Brehm	439	510 to 540	Brehm